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REPORT

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THE DESIGN, CONSTRUCTION, AND TESTING
OF A LIQUID BEARING
INCORPORATING A BUILT-IN PUMP

RM-142-65

June 1965

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FOREWORD

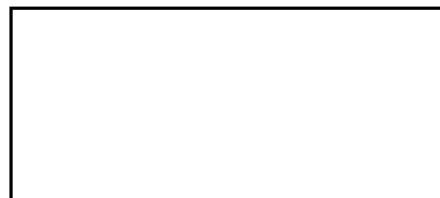
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of the Development Objectives of []

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ABSTRACT

The purpose of this assignment was to design, construct, and test a liquid bearing that is a radical departure from the type employed previously. The bearing is required to be self-powered and to incorporate its own fluid pump.

This report summarizes the content of the interim progress report dated February 1965, and details the further tests conducted to determine the efficiency of the design.

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1. INTRODUCTION

The liquid bearing design described in this report and now known as the "Rotatron" was developed to overcome the many disadvantages inherent in the liquid bearings now being used.

A liquid bearing per se is a bearing on which a load is supported by a liquid. Liquid bearings are used to support film while it is transported through the various tanks of solutions used in the developing process. These bearings support the film on "jets" of liquid (developer, wash water, etc.) which is pumped into each bearing and subsequently through a combination of orifices in such a manner that the film is forced to ride upon these jets.

STAT The load on the bearings is a product of both the length of the film in the processor and the speed (fpm) of transport. (Refer to Assignment) The load on an individual bearing depends on its location along the film path, that is, the load is accumulative from bearing to bearing and, as it increases, greater support force must be provided by the jets.

The Rotatron bearing was designed to:

- 1) Lower the unit pressure on the film
- 2) Provide a definite degree of transport assist
- 3) Be independent of other bearings
- 4) Eliminate conventional plumbing
- 5) Obviate the need for circulating pumps
- 6) Provide a simple method of cushion control
- 7) Provide a simple means of film tension regulation
- 8) "Float" the film around the bearing center
- 9) Cause the film to self-center on the bearing

- 10) Be easily adaptable to the module-type processor
- 11) Eliminate the harmful effects inherent in conventional mechanical bearing systems.

2. TECHNICAL DISCUSSION

2.1 PHYSICAL DESCRIPTION

Essentially, the prototype Rotatron is a squirrel-cage axial-vane pump, 4 inches in diameter, with 12 blades set at 30 degrees from the radial (Figure 1). The pump is "caged" in a helix of 1/8-inch diameter wire, one-half of which is left-hand wound and the other half right-hand wound, on a pitch of 1/4 inch. Approximately 120 degrees of the circumference of the underside is covered by a plate which extends for the entire length of the blades. The cage rests in contoured cradles on the mounting plate thus making it possible to rotate it through 360 degrees (Figure 2).

2.2 TEST SETUP

To facilitate testing under realistic conditions, the pump was mounted on the side wall of a specially constructed tank, three walls of which were plate glass. The tank (Figure 3) was approximately 24 inches square by 42 inches deep. Water level in the tank covered the bearing to a depth of approximately 4 inches. The tank capacity at operating level was 104 gallons.

The Rotatron was driven by a 1/8-horsepower electric motor through "V" belts, various pulleys (four in the system), and a 2 to 1 speed reducer, with the final driveshaft entering the tank through a water-tight sleeve bearing and connected to the Rotatron by a rubber flexible-coupling. This drive system was used only for testing (Figure 4). The final Rotatron will be designed to be driven directly by a motor governed to operate at speeds required by the individual bearing.

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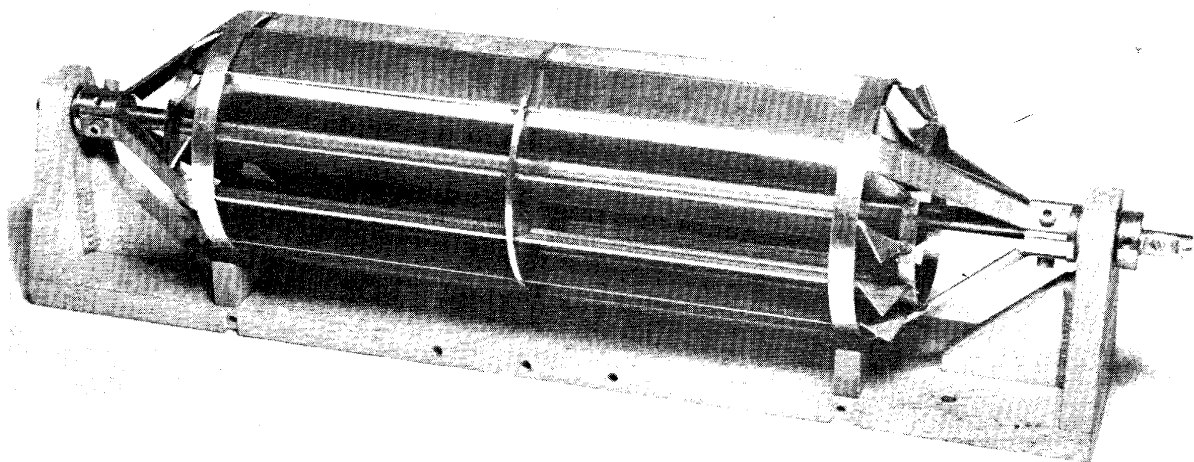
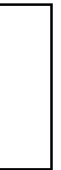


Figure 1. Rotatron Impeller

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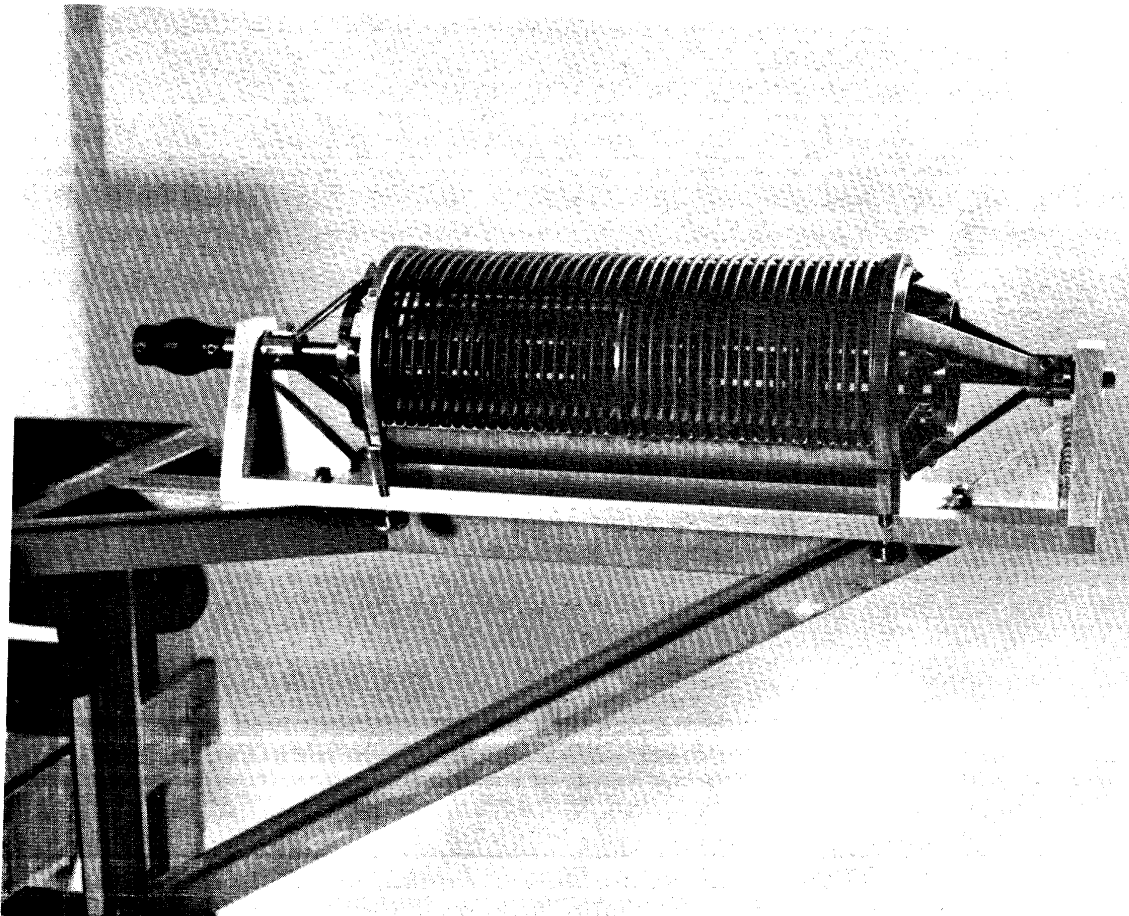


Figure 2. Rotatron on Test Tank Support

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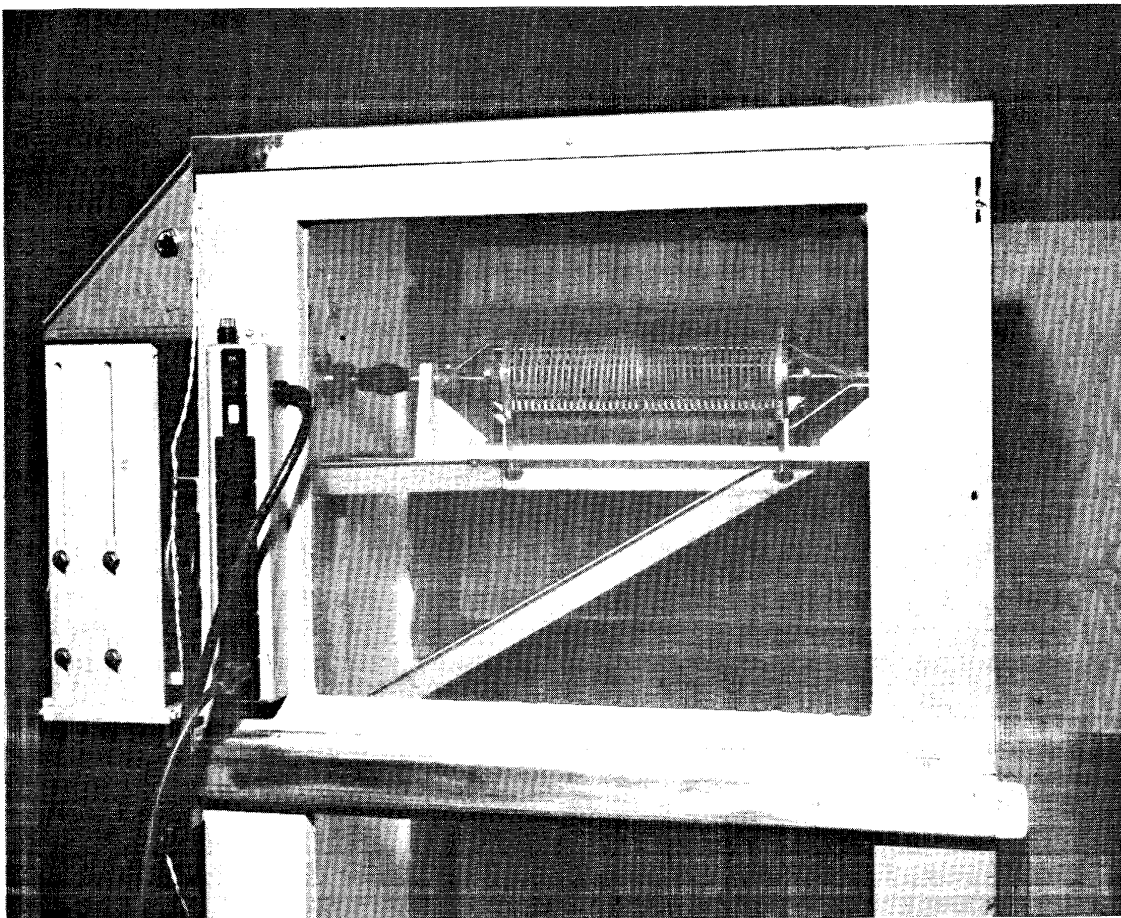


Figure 3. Rotatron In Test Tank

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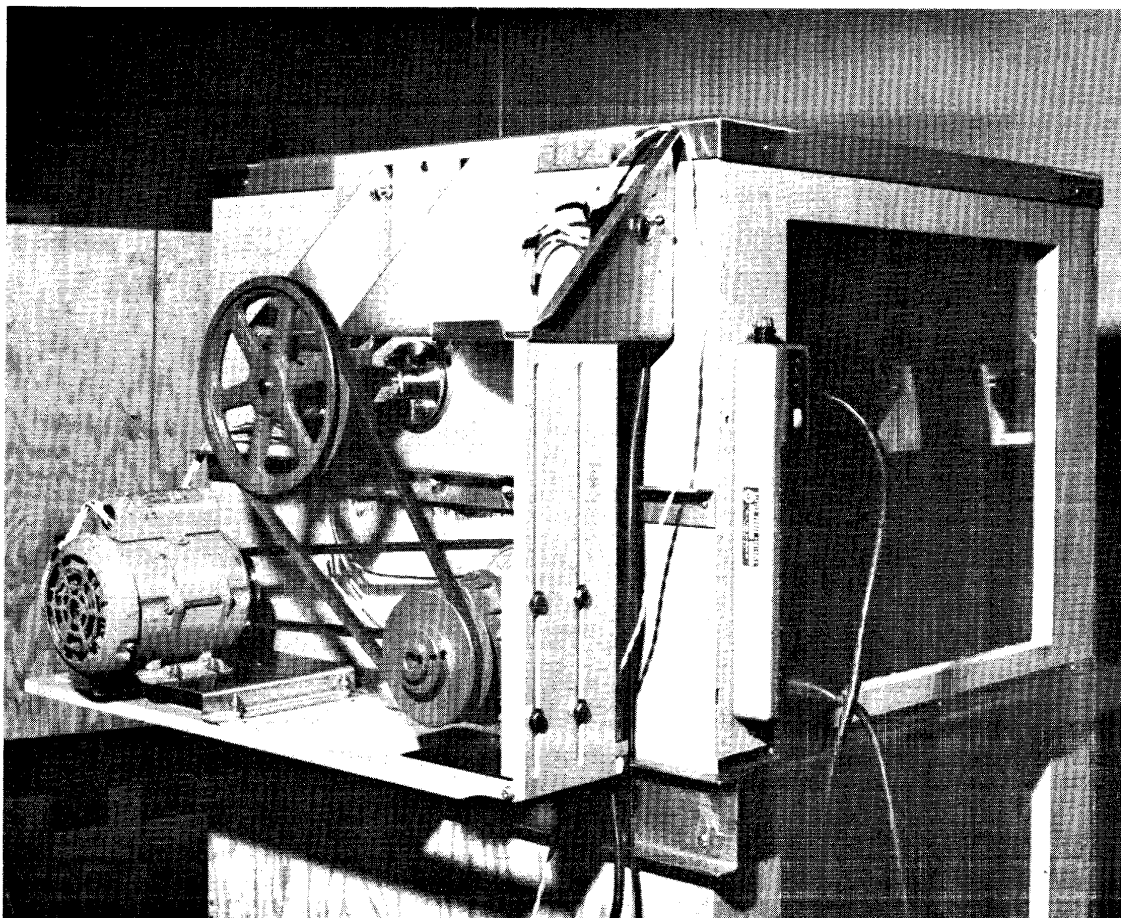


Figure 4. Drive System

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2.3 TEST PROCEDURE AND RESULTS

2.3.1 Rotatron Without Film

The Rotatron was first run at a speed of approximately 445 rpm without any film to study the flow pattern. The relative pumping efficiency was unknown, and water was cascaded over the top of the tank before the pump was up to speed. With the pump approximately 6 inches below water level, a speed of 445 rpm was more than tolerable when running without film.

2.3.2 Rotatron With Film Loop

The next step was to run the pump at slower speeds using a loop of film to determine the effect of speed on bearing (cushion) capability. Inasmuch as the output pressure and flow volume were yet to be evaluated, there was no way of calculating the speed (rpm) required for a given bearing load.

A loop was formed of 9-1/2 inch thin-base mylar leader with a regulation spool (1-1/2 pounds) at the bottom of the loop so that the bearing and spool were approximately 30 inches on centers. At 150 rpm, a very adequate cushion was provided but the loop immediately moved off center. It was obvious that the helix cage (Figure 5) was not sufficiently effective to cause the film to "track."

The cage had been installed so that the helixes would tend to direct the water to converge in the direction of pump rotation, the same direction as film travel. When the cage was reversed, the film still persisted in sliding off center. Two metal clips (Figure 6) were attached to the end of the cage at top center to keep the film on the bearing. The restraining force was so slight that measurement was not possible with available equipment. The force was estimated to be less than 1/4 ounce.

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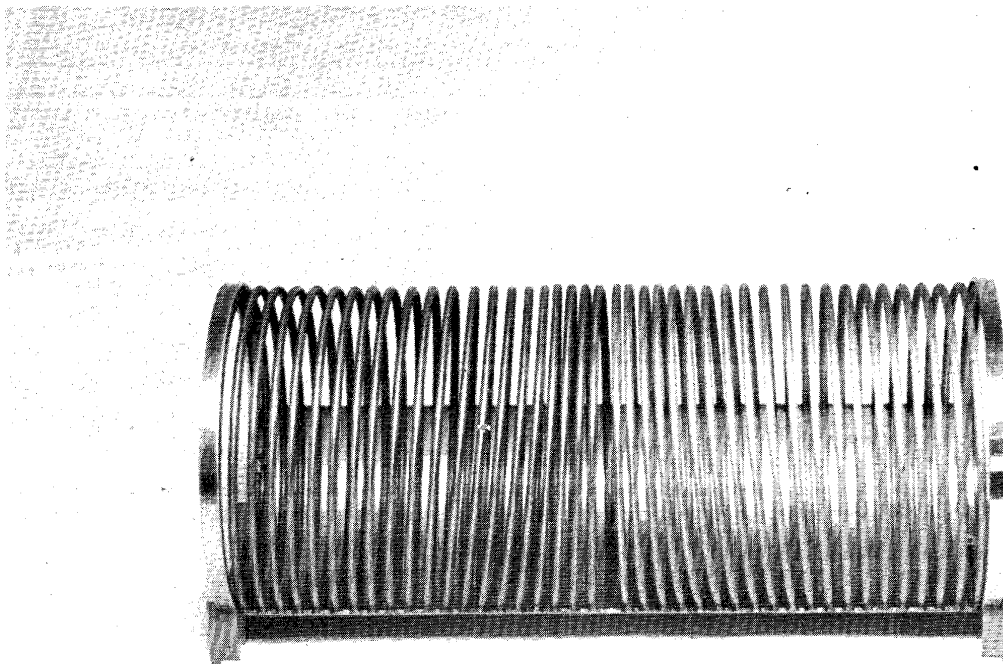
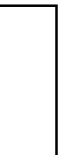


Figure 5. Helix Cage

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Figure 6. Stable Cushion

2.3.3 Bearing Shape Versus Film Tracking

It had been surmised that the film would track on a "crowned" liquid bearing in much the same way that a leather belt would ride a crowned pulley. Instead, it appeared that the film was sliding off in much the same manner as a surfer slides down a breaker.

To study the shape of the emission of the fluid from the pump, the water level was gradually dropped so that the contour of the bearing could be observed. The pump had been designed to provide this "crown."

Since the film slid from the "crown," it was thought that centering of the film would occur if a "valley" or "trough" was provided in the cushion. (Refer to Assignment) A girdle of perforated aluminum sheet was wrapped around the helix cage midway between the cage end rings. The aluminum sheet (0.025-inch thick) was perforated throughout approximately 50 percent of its area. The width of the girdle was equal to one-half the length of the cage. The girdle definitely reduced the sliding off center but, at the same time, reduced the depth of the cushion.

To restore the cushion depth, the speed was increased to 275 rpm. It now appeared that the restriction was too great over too wide an area, and the floor of the valley was too flat. To rectify this condition, the ends of the perforated sheet were trimmed out for about 50 percent of the area at each end of the girdle to approximately 25 percent of the total length. With the ends of the girdle trimmed out (Figure 7) to feather the flow, the center of the girdle was further restricted by wrapping a 1/2-inch wide tape on each side of the 1/2-inch wide metal retaining clamp. Thus, the center of the cage was closed off completely by a band 1-1/2 inches wide. The resulting flow pattern can be clearly seen in Figure 8. Again, the water level was lowered to just cover the cage for this photograph.

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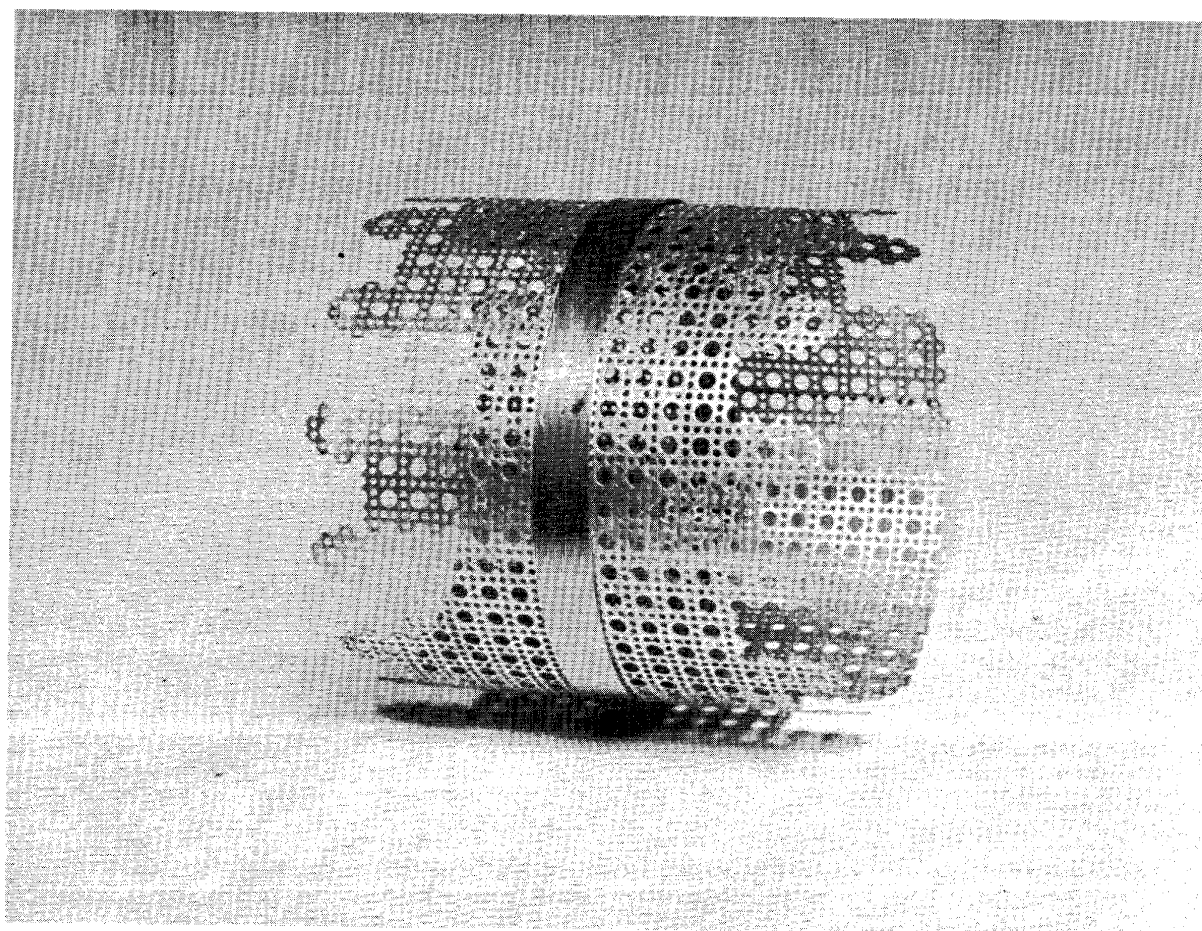
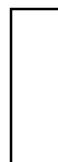


Figure 7. Girdle

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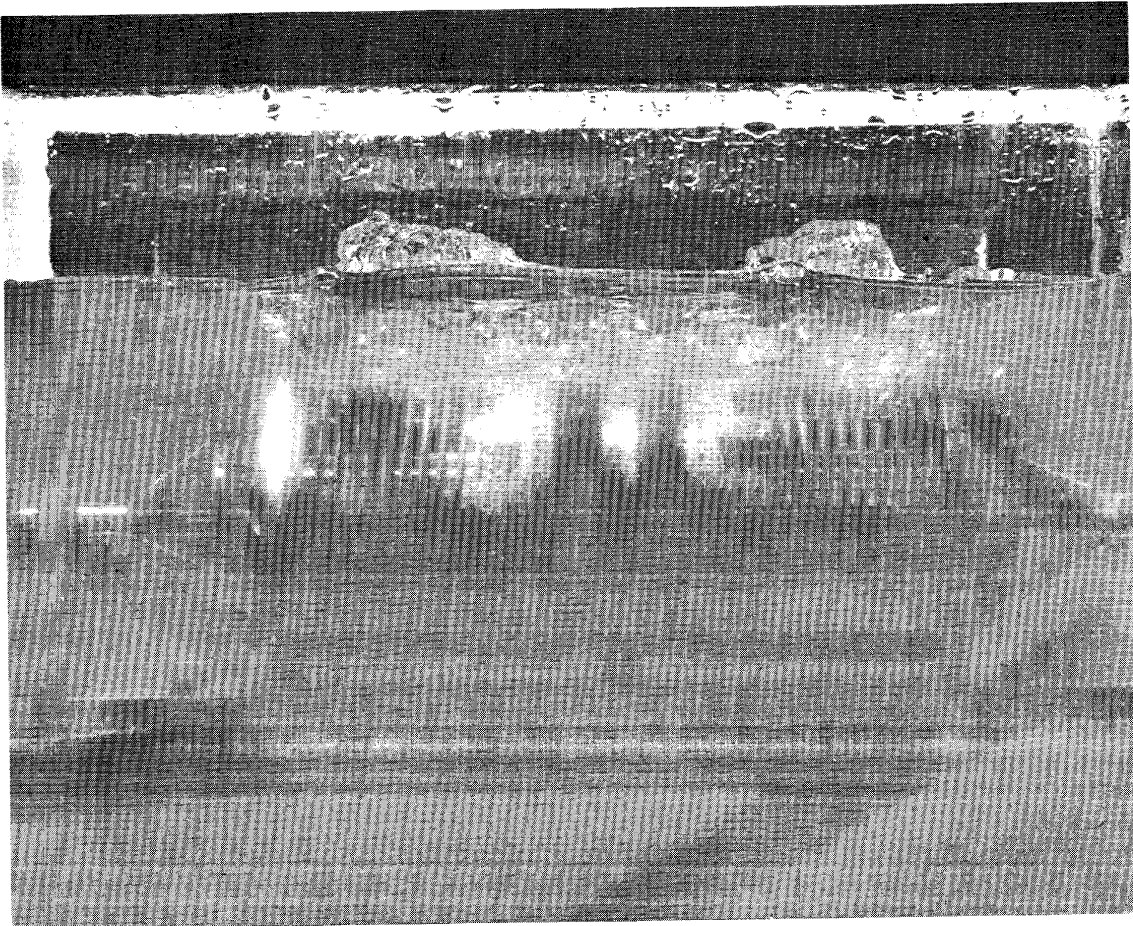
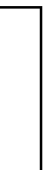


Figure 8. Girdled Helix Flow Pattern

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The theory that this type of flow pattern, which is constant about the periphery of the bearing, would tend to keep the film centered on the bearing in a "trough" of the liquid proved correct to a marked degree. However, the 9-1/2-inch film tended to hunt slightly from side to side, but the force to restrain it was now being reduced to a feather touch. It appeared that with a proper flow pattern, this slight hunting could also be eliminated. Furthermore, it was reasoned that this hunting tendency might be aided by the unstable flow of fluid as it escaped from under the film, the pressure being reduced as the flow reached the outer edges.

To offset this hunting tendency, two 1/2-inch wide strips of 0.010-inch thick metal were wrapped around the cage at the extreme ends, thus reducing the effective liquid bearing width to 9-5/8 inches. The effectiveness of this modification was not sufficient to establish any conclusion, because the film continued to hunt from side to side between the two clips.

With the installation of the girdle, the loop over the bearing became quite stable, as shown in Figure 6, and concentricity was readily controlled by positioning the cage bottom plate to equalize the pressure distribution. Increasing the pump speed, which increased cushion depth, also changed the location of the maximum pressure area necessitating a change of the position of the cage bottom plate to restore concentricity.

2.3.4 Film Transport Assist

At various times during the tests, the film loop travelled in the direction of pump rotation. This action occurred until the splice came to either the spool or the bearing. The splice had been made by butting the edges of the film and applying mylar tape (1-mil thick and 1-inch wide) to both sides of the film. This relatively stiff splice (water temperature 66°F) increased the normal bending forces.

The film loop was removed from the tank and allowed to remain at room temperature for approximately 1 hour. A 4-pound spool was placed in the loop and the loop was restored to the tank over the bearing (Figure 9). The pump was started and the film then moved in a clockwise direction at the rate of approximately 1 foot per second, rotating the hanging spool in so doing. This action continued until the film became stiffened by the cold water.

During this observation, the film tended to remain quite steady on the approximate center of the bearing. As stated elsewhere in this report, the two cage helixes were wound in opposite directions for the purpose converging or diverging the liquid flow; however, it appears that the influence of the 1/8-diameter wires plus the low pitch of the helix winding is insufficient to satisfy the requirements of this type of vector flow control, although all indications are that this is within the realm of possibility.

2.3.5 Fluid Dynamics Reaction

2.3.5.1 Loop Instability

Up until this stage of testing effort, the depth of cushion had not been of importance; but, with the hunting reduced to a minimum, attention was now turned to cutting the cushion depth. It was thought that an overall more stable cushion would result if the depth were reduced, this being accomplished by reducing the speed to 150 rpm.

With the film restrained from floating off the bearing and the cushion depth reduced to approximately 3/8 inch at the top (12 o'clock position) due to the lower rpm, it was observed that the film now had a tendency to undulate, the motion starting on the "off" side at about the 3 o'clock position. This loping action did not occur at even intervals but

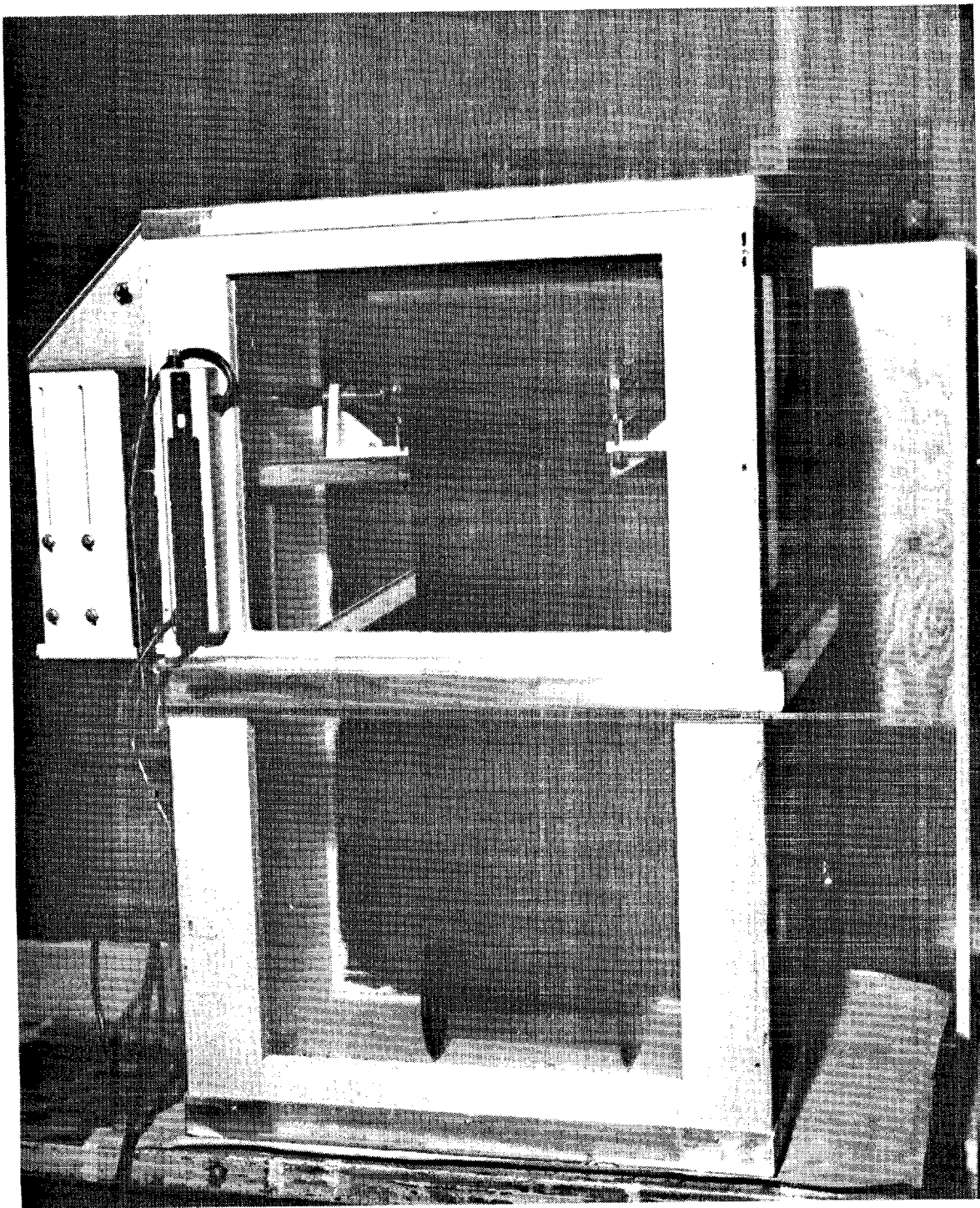


Figure 9. Film Loop In 104-Gallon Test Tank

the average rate was approximately 60 cps. The film would move away from the bearing to double the depth of the cushion and then fall back to about one-half the depth of the cushion. This action, in effect, shortened the loop, raising the bottom spool. As the depth of the cushion increased, the pressure would drop due to a greater "escape" area, the weight of the spool would then tighten the loop, and the action would repeat itself. The irregularity was undoubtedly due to the damping action of the water in the tank.

The weight of the spool was then increased to 4 pounds, (the equivalent of the load on the last bearing in a film processor running 9-1/2 inch aerial negative at a speed of 20 fpm), to determine if this would affect the frequency. The additional weight required an increase in pump speed from 150 to 185 rpm to restore the cushion depth of approximately 3/8 inch. The loping tendency persisted at about the same rate.

2.3.5.2 The Stable Cushion

The test setup in use, with the weighted spool hanging in the loop, provided little or none of the damping that would exist if the film continued around other bearings. To provide a degree of damping, two 1-pound weights were suspended to the hubs of the spool by rubber bands. The pump speed was increased to 250 rpm to maintain the cushion depth. The damping action provided by the suspended weights minimized the pulsing tendency but did not eliminate it entirely. The frequency, however, was irregular and the magnitude was less. This led to the thought that the film was reacting to a jet-pressure effect caused by the greater volume of liquid emanating from the pump in the center. The greater spool weight (6 pounds) now required a greater mean pressure against the total projected area of the film. This undoubtedly meant that there was better

pressure distribution and that the release (flow) of the liquid out from the film was such that the pressure distribution was more even throughout the bearing area. Though the cushion was now quite stable it was eccentric, the cushion being deepest in the area where the pulsating (3 o'clock) was taking place. The cage was rotated counterclockwise (contra pump-rotation) thereby increasing the pressure on the entering side of the bearing and, conversely, decreasing the pressure on the exit side. This allowed the liquid cushion depth in this area to decrease, which at the same time, increased the unit pressure in the area causing the reappearance of the loping of the loop.

2.3.6 Load Capability

The load capability of the Rotatron bearing appears to be limited only by the strength of the film. It also appears that the processing speed will be no longer limited to the film strength because each Rotatron bearing can contribute to film transportation, thus reducing the accumulative load.

The cushion depth appears to remain relatively constant over a speed variation of ± 10 percent. An effort will be made to determine this during the next research phase.

2.3.6.1 Pressure Distribution

In order to determine what is responsible for the various behavior idiosyncrasies of the prototype Rotatron, a plastic canopy, simulating the 9-1/2 inch film with a 7/32-inch cushion, was fabricated (Figure 10). This canopy contained 161 probe points, each of which was closed with a screw when not used by the threaded probe. The screws, like the probe, were flush with the inside surface of the 3/8-inch thick plastic canopy.

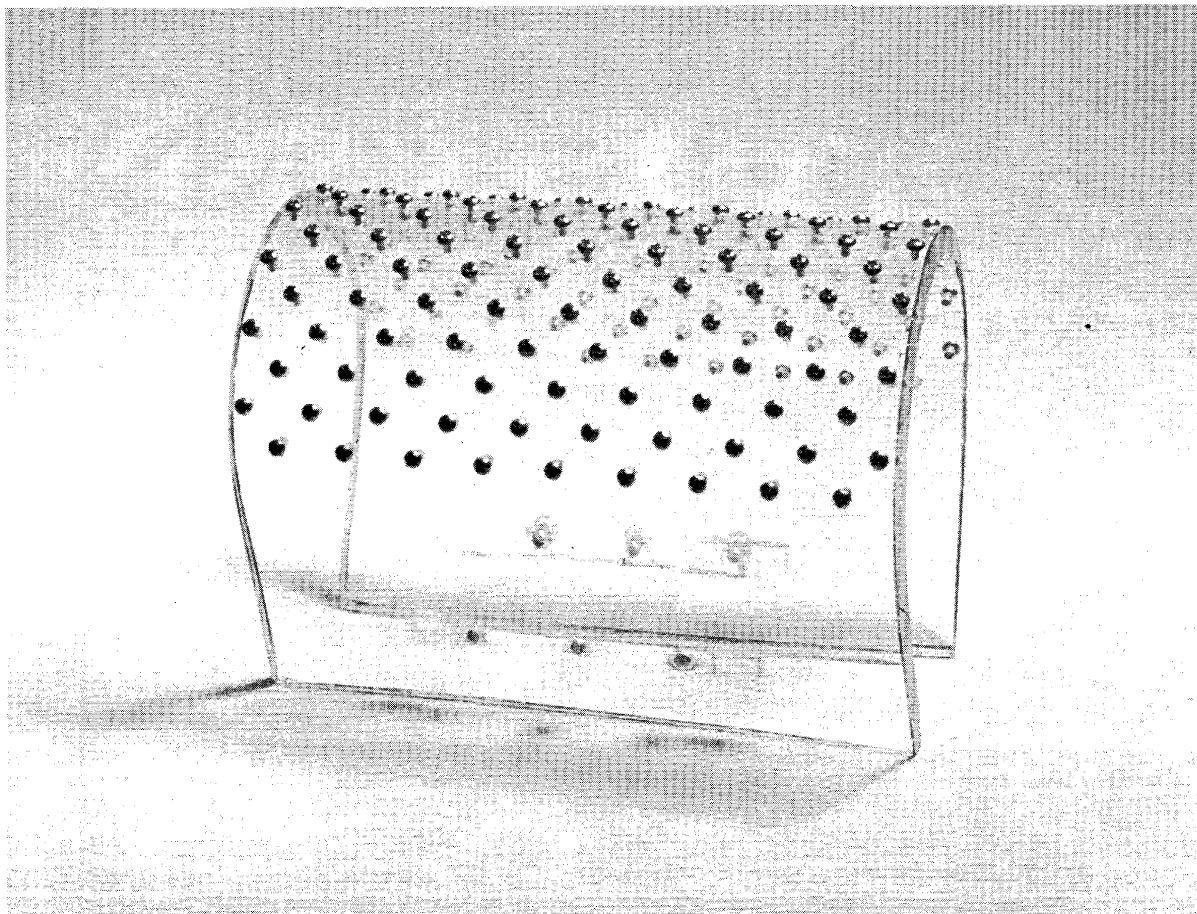
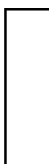


Figure 10. Canopy With 161 Probe Points

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Test runs were made at three speeds: 296, 356, and 420 rpm with the canopy installed over the helix cage with no girdle. A fourth run was made at 420 rpm with the girdle in place. The resultant pressure plots, seven in all (four direct, three calculated from the original four direct), clearly show the pressure distribution (Pressure Plots 1, 2, 3, 4, 1A-1, -2, and -3; 2A-1, -2, and -3; and 3A-1, -2, and -3).*

The numerals on the plots are "inches" read on an inclined manometer (slope = approximately $14\frac{1}{2}$ degrees, slope factor = 4.123), using chemically pure carbon tetrachloride (cp/CCl_4). The factor for reducing manometer readings in inches to pounds per square inch is 9.506×10^{-3} . The plot numbers are in manometer/inches to make the pressure differentials easier to visualize.

2.3.6.2 Pressure Versus RPM

Theoretically, hydraulic pressure varies as the square of the velocity. Stated in simpler words, it takes 4 times as much pressure to deliver 2 times the volume. Examination of the pressure plots read at various speeds indicate that the pressure does vary as the square of the rpm. This fact also means that the flow (gpm) varies directly as the impeller velocity. This would indicate a relatively high efficiency for this particular design.

2.3.7 Horsepower Requirements

Theoretically, hydraulic horsepower is calculated on the basis of quantity of flow multiplied by pressure:

$$\text{gpm} \times \text{psi} = \text{hp} \quad (1.71 \text{ gpm} \times 1000 \text{ psi} = 1 \text{ hp})$$

therefore

$$\frac{\text{gpm} \times \text{psi}}{1.71 \times 10^3} = \text{hp}$$

* See Appendix A

2.3.7.1 Pumping Capability

To evaluate the horsepower requirements of the Rotatron bearing, a test was run to determine the fluid pumped at the various rpm at which pressure readings were made. To accomplish this, a plastic tube (Figure 11) of the same outside diameter as the bearing was placed over the impeller. A smaller tube led the flow of fluid through the side of the test tank to a standpipe, establishing a hydraulic head equal to that in the tank. Water was supplied to the tank through a flowmeter at a rate sufficient to maintain the established head above the bearing. A pressure probe was inserted in the plastic tube surrounding the impeller. Another probe was inserted in the outlet tube to read the back pressure in the outlet line. The difference between the pressure readings would represent the actual pressure required to deliver (pump) a given quantity of fluid. Pressure readings were made using the inclined manometer and verified with simple standpipe readings in inches of water. The pressure readings at given revolutions per minute were virtually identical with the average of the 161 point readings taken with the plastic canopy.

2.3.7.2 Measured Volume Flow

The gallons per minute and the pounds per square inch at various rpm are given in Table 1.

Examination of average psi readings reduced from pressure plots 1, 2, and 3 combined with the flow rates at the corresponding rpm, show that the hydraulics horsepower requirements are extremely low. It should be noted again here, that the flow varies with the velocity and the pressure varies as the square of the velocity.

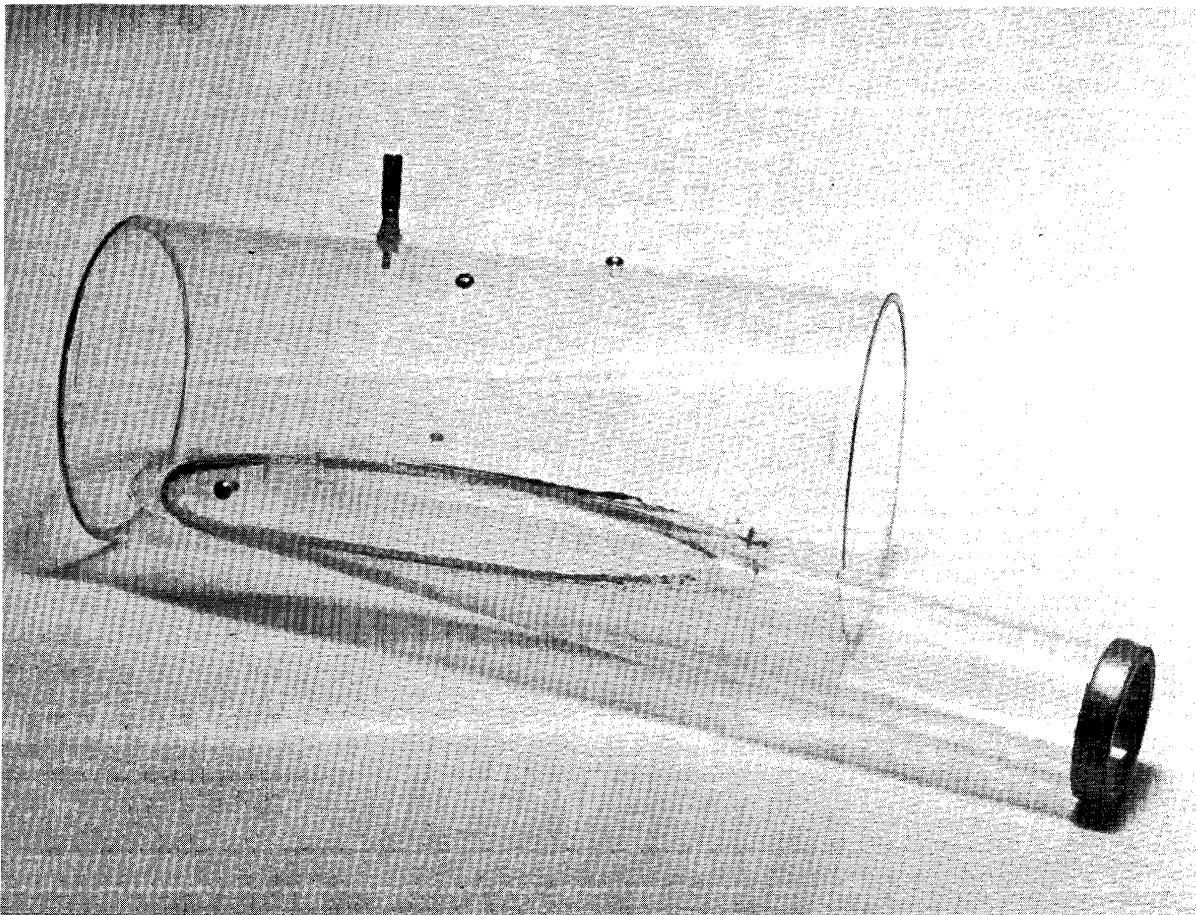


Figure 11. Flow Test Incasement

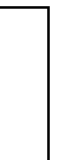


TABLE 1
GALLONS PER MINUTE AND
POUNDS PER SQUARE INCH
AT VARIOUS RPM

<u>RPM</u>	<u>GPM</u>	<u>PSI</u>
296	9.35	0.098
356	11.3	0.141
467	14.7	0.243

applying the horsepower formula, $\frac{\text{gpm} \times \text{psi}}{1.71 \times 10^3} = \text{hp}$:

$$\text{at 296 rpm, } \frac{9.35 \times 0.098}{1.71 \times 10^3} = 0.00055 \text{ hp}$$

$$\text{at 356 rpm, } \frac{11.3 \times 0.141}{1.71 \times 10^3} = 0.000933 \text{ hp}$$

$$\text{at 467 rpm, } \frac{14.7 \times 0.243}{1.71 \times 10^3} = 0.00209 \text{ hp}$$

2.3.8 Bearing Loads, Theory Versus Practice

On the basis of tests run, it appears that the Rotatron speed (rpm) can be proportional to the load requirements. The pressure required for a given load, based upon the actual load (spool weight) during rpm runs, is consistent with the psi over a projected area of the film. To put it more understandably, so many pounds per square inch multiplied by the number of square inches of the film over the bearing approximates very closely the weight of the spool. By the same token, the increase in rpm required to maintain the same cushion depth (approximately) with a heavier load on the spool is very consistent with the psi generated by the rpm increase.

Assume that the weight of the spool in the test loop was doubled. This would require twice the psi to maintain the desired cushion. If the pressure increase is 2, the speed increase must vary as the square root of 2, or 1.414.

For example: say the original rpm is 150 and the psi is 1.5. The new pressure required is 3.0 psi:

$$\left(\frac{1.414 \times 150}{150}\right)^2 = \frac{X}{1.5}$$

$$\left(\frac{210}{150}\right)^2 = \frac{X}{1.5}$$

$$(1.414)^2 = \frac{X}{1.5}$$

$$2 = \frac{X}{1.5}$$

$$X = 2 \times 1.5 = 3.0 \text{ psi}$$

2.3.9 Rotatron Design Parameters

2.3.9.1 Bearing Diameter

The diameter of the experimental Rotatron bearing was chosen as an optimum size based upon the force required to bend film through 180 degrees.* The bend radius of 2-1/4 inches also provided a larger projected bearing area, thus requiring lower unit pressure for a given load. Lower unit pressure also requires a lower flow velocity which is less sensitive to flow variations caused by slight changes in fluid cushion depth due to changes in film drag during processing, thus contributing greatly to the stable cushion.

2.3.9.2 Impeller

The number of impeller blades (12) was chosen to give a space between each approximately equal to the blade chord (width). (See Figure 1.) This proportion is in keeping with optimum design criteria generally used in pumps and fans of this type. The blade width was a function of the frontal area exposed at the angle of attack (45 degrees to the tangent at the blade leading edge). Each blade was assumed to be doing a fraction of pumping equivalent to the number of blades, that is, 10 blades at 10 percent, or 12 blades at 8.33 percent; in effect, 1 blade at 100 percent.

For example:

Rotatron blade width = 0.75 inch

12 blades at 8.33 percent = 1 at 100 percent

effective blade length = 10 inches.

*Reference Report 974-002, "Determination of the Force Required to Bend Film 180 Degrees Over Different Radii of Curvature," February, 1965.

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$$\text{Pumping capacity} = \frac{A \times B \times \text{rpm}}{C} = Q$$

where

A = blade width

B = effective blade length

C = 231 (cubic inches per gallon)

Q = gpm.

It has been stated that the pumping efficiency of the Rotatron is relatively high. Here is a comparison of the theoretical and actual output based upon the above formula.

$$\text{For 296 rpm: } \frac{0.75 \times 10 \times 296}{231} = 9.6 \text{ gpm}$$

Actual test reading was 9.35 gpm

$$\text{For 356 rpm: } \frac{0.75 \times 10 \times 356}{231} = 11.55 \text{ gpm}$$

Actual test reading was 11.3 gpm

$$\text{For 467 rpm: } \frac{0.75 \times 10 \times 467}{231} = 15.17 \text{ gpm}$$

Actual test reading was 14.7 gpm

The formula used above is the result of emperical and theoretical data. Inasmuch as the impeller was designed to suit the bearing configuration and is a radical configuration as impellers go, it was not deemed advisable to spend time designing a prototype by more academic methods. The test results indicate that this approach was adequate.

While a smaller diameter Rotatron is feasible, the present diameter allows room for a stator with a smaller pitch impeller. The employment of a stator is indicated by the results of tests run with a perforated screen cylinder in place of the wire helix cage.

2.3.9.3 Perforated Screen Cage

Observations of the film behavior, together with the pressure point readings recorded when the wire helix cage was used, led to the thought that a more even and more stable fluid cushion would result if the direct effluence of liquid from the impeller blades was eliminated. To accomplish this, a thin perforated sheet of aluminum, rolled to the 4-1/2 inch diameter of the bearing, was fabricated.

The holes in the screen constitute 28 percent of the area. Test runs were made at various rpm. The Rotatron was started with the water level just below the impeller. As the water level was raised to normal, the build-up of the cushion was easily observed. The cushion started building in the center, and the crown (barrel shape) of the cushion was clearly apparent. The surface was smooth and showed no turbulation. When the water level was up to normal, runs were made with film loops of 9-1/2, 6.6, and 5 inch widths, with weight spools at the bottom of the loops. All widths of film quickly slid off the cushion crown, but when restrained from doing so, the loops rode smoothly on the cushion which was very symmetrical. It was also observed that the cushion depth was greater at a given rpm and weight of spool than it had been with the helix cage. It was deduced that this was because there was less flow losses due to the space between the blade edges and the inside surface of the screen. This space became a sort of plenum with perforated screen providing a large area for fluid escape.

3. SUMMARY

In summary, on the basis of the test program conducted, the objectives laid out at the beginning of this program appear to have been met in a most satisfactory manner. Work outstanding to complete this program involves testing of a redesigned cage, to replace the original spiral-wound cage, and processing of film over the bearing to establish if any undesirable mottling or marking is caused.

With the satisfactory conclusion of these two outstanding tests, further development must await the authorization to design and construct a production model. The production model would incorporate all the proven features of the prototype bearing, together with the requirements of mounting, direct motor drive, rpm control, and other features in a "modular" package.



STAT

APPENDIX A
PRESSURE PLOTS

TOP CENTER
(Drive End)

		-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
	1		* 6.78		* 6.48		* 5.34		* 5.34		* 4.77		* 4.74		* 6.30		* 6.46	
1		* 9.09		* 8.88		* 8.38		* 8.45		* 8.15		* 8.68		* 8.67		* 9.80		* 9.10
	2		* 9.77		* 9.23		* 9.38		* 10.34		* 10.35		* 10.35		* 10.30		* 10.50	
2		* 11.13		* 10.11		* 9.55		* 10.63		* 11.72		* 12.59		* 10.15		* 11.40		* 9.12
	3		* 10.89		* 9.27		* 10.25		* 11.48		* 12.05		* 11.82		* 11.20		* 10.70	
3		* 12.55		* 10.09		* 9.60		* 11.04		* 12.31		* 12.60		* 11.83		* 10.96		* 8.70
	4		* 11.04		* 9.66		* 10.63		* 11.79		* 12.12		* 11.79		* 10.62		* 9.26	
4		* 12.57		* 10.18		* 9.90		* 11.34		* 12.42		* 12.12		* 11.88		* 10.16		* 8.70
	5		* 11.28		* 9.69		* 10.62		* 12.26		* 12.99		* 12.19		* 10.50		* 8.66	
Film Centerline →	5	* 12.30		* 10.32		* 10.24		* 12.18		* 13.04		* 12.94		* 11.98		* 10.50		* 9.90
	6		* 11.22		* 9.47		* 10.89		* 12.40		* 12.82		* 12.29		* 10.60		* 8.48	
6		* 12.09		* 9.56		* 9.77		* 11.80		* 13.19		* 12.48		* 11.20		* 9.70		* 7.66
	7		* 11.02		* 9.09		* 10.69		* 12.94		* 13.00		* 12.19		* 9.70		* 8.66	
7		* 12.35		* 9.44		* 9.65		* 11.38		* 13.30		* 12.77		* 10.97		* 9.10		* 7.06
	8		* 10.17		* 8.95		* 10.35		* 12.44		* 12.79		* 12.04		* 9.40		* 7.70	
8		* 12.31		* 9.71		* 9.16		* 10.82		* 12.34		* 12.48		* 10.00		* 9.00		* 7.26
	9		* 9.79		* 8.51		* 9.46		* 10.62		* 10.94		* 10.50		* 8.90		* 8.30	
9		* 10.68		* 7.88		* 7.49		* 8.34		* 8.71		* 8.50		* 8.58		* 7.90		* 7.24
	10		* 6.29		* 5.23		* 5.14		* 6.35		* 6.35		* 7.34		* 6.70		* 6.24	

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches.

Pressure Plot No. 1A-1
296 RPM

TOP CENTER
(Drive End)

		-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
	1		* 7.02		* 6.95		* 6.05		* 5.77		* 4.75		* 4.67		* 6.26		* 7.48	
1		*10.17		* 9.76		* 9.22		* 8.39		* 7.70		* 9.14		* 9.00		*10.82		*10.30
	2		*10.13		*10.36		*10.52		*10.72		*11.13		*10.42		*10.42		*11.63	
2		*11.89		*11.34		*11.13		*11.19		*11.82		*12.54		*11.48		*12.50		*10.17
	3		*12.27		*10.94		*11.26		*12.10		*12.63		*11.96		*11.92		*12.18	
3		*12.98		*11.20		*10.78		*11.85		*12.93		*12.93		*11.96		*12.58		* 9.82
	4		*12.30		*10.77		*11.82		*12.23		*12.78		*12.03		*11.62		*10.58	
4		*13.12		*11.26		*10.90		*12.01		*13.00		*12.87		*11.86		*12.03		* 8.74
	5		*12.33		*10.93		*11.40		*12.74		*13.22		*12.67		*11.32		*10.11	
Film Centerline →	5	*12.90		*11.40		*11.60		*12.55		*13.47		*13.40		*11.97		*11.60		* 9.08
	6		*12.20		*10.64		*11.48		*12.98		*13.13		*12.53		*11.46		* 9.40	
6		*12.83		*10.64		*11.07		*12.08		*13.52		*12.82		*11.55		*10.75		* 8.83
	7		*12.10		*10.12		*11.21		*13.20		*13.23		*12.55		*10.54		*10.03	
7		*13.41		*10.62		*10.84		*11.89		*13.50		*12.92		*11.41		*10.48		* 8.20
	8		*11.25		*10.11		*10.86		*12.70		*13.00		*11.90		*10.32		* 8.80	
8		*13.40		*10.92		*10.33		*11.58		*12.84		*12.51		*10.80		*10.04		*12.25
	9		*10.86		* 9.32		* 9.77		*10.72		*11.00		*11.13		* 9.85		* 9.35	
9		*11.75		* 8.56		* 7.84		* 8.23		* 8.66		* 9.14		* 9.08		* 9.22		* 8.18
	10		* 6.95		* 5.95		* 5.64		* 5.98		* 6.24		* 6.74		* 7.71		* 7.43	

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches from Pressure Plot

No. 2A-1 divided by $\left(\frac{\text{RPM, Plot No. 2A-1}}{\text{RPM, Plot No. 1A-1}}\right)^2$

$= \left(\frac{357}{296}\right)^2 = 1.454$

Approved For Release 2002/09/03 : CIA-RDP78B04747A002800040001-7

Pressure Plot No. 1A-2

A-3

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		* 6.85		* 6.75		* 5.47		* 5.20		* 4.37		* 4.37		* 6.07		* 7.36	
1	* 9.44		* 9.32		* 8.55		* 7.75		* 7.75		* 8.35		* 8.54		* 11.32		* 10.13
2		* 10.62		* 9.83		* 9.93		* 11.60		* 11.71		* 11.21		* 11.12		* 12.01	
2	* 12.80		* 11.31		* 11.01		* 11.55		* 12.80		* 14.24		* 13.00		* 14.10		* 10.03
3		* 13.30		* 10.62		* 11.02		* 13.45		* 14.28		* 13.40		* 13.55		* 13.32	
3	* 13.86		* 11.01		* 10.42		* 12.60		* 14.98		* 14.98		* 13.50		* 13.30		* 9.23
4		* 13.20		* 10.52		* 11.61		* 14.24		* 14.59		* 13.85		* 12.95		* 10.02	
4	* 14.30		* 11.30		* 10.59		* 12.42		* 15.27		* 14.97		* 13.48		* 12.11		* 9.43
5		* 12.54		* 10.73		* 11.63		* 15.12		* 15.32		* 14.32		* 13.18		* 9.57	
5	* 13.30		* 11.55		* 11.43		* 11.39		* 15.97		* 15.70		* 13.53		* 12.50		* 8.53
6		* 12.35		* 10.32		* 12.12		* 15.37		* 15.32		* 14.48		* 12.94		* 8.53	
6	* 13.14		* 10.32		* 10.91		* 12.50		* 15.86		* 14.80		* 13.23		* 10.56		* 9.03
7		* 11.80		* 9.67		* 11.30		* 15.68		* 15.33		* 14.68		* 11.10		* 9.61	
7	* 14.07		* 10.15		* 10.46		* 12.10		* 15.66		* 15.25		* 12.71		* 10.03		* 7.75
8		* 11.87		* 10.28		* 11.12		* 14.90		* 14.93		* 14.00		* 10.33		* 8.84	
8	* 13.95		* 10.58		* 9.95		* 11.13		* 15.10		* 14.80		* 11.52		* 9.89		* 7.85
9		* 10.40		* 8.80		* 9.34		* 11.92		* 12.11		* 12.03		* 10.13		* 9.25	
9	* 11.83		* 8.15		* 7.68		* 7.70		* 8.70		* 9.05		* 9.74		* 8.45		* 8.05
10		* 6.46		* 5.59		* 5.27		* 5.66		* 5.76		* 6.26		* 7.75		* 7.86	

Film Centerline →

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches from Pressure Plot

No. 3A-1 divided by $\left(\frac{\text{RPM, Plot No. 3A-1}}{\text{RPM, Plot No. 1A-1}}\right)^2$

$$= \left(\frac{420}{296}\right)^2 = 2.013$$

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		*10.20		*10.10		* 8.80		* 8.40		* 6.90		* 6.80		* 9.10		*10.88	
1	*14.80		*14.20		*13.40		*12.20		*11.20		*13.30		*13.10		*15.76		*15.00
2		*16.20		*15.08		*15.30		*15.60		*16.20		*15.14		*15.15		*16.92	
2	*17.30		*16.50		*16.20		*16.28		*17.20		*18.24		*16.80		*18.19		*14.90
3		*17.86		*15.92		*16.40		*17.60		*18.36		*17.40		*17.36		*17.24	
3	*18.90		*16.30		*15.68		*17.24		*18.80		*18.80		*17.40		*18.30		*14.28
4		*17.90		*15.68		*17.20		*17.80		*18.60		*17.52		*16.90		*15.40	
4	*19.10		*16.40		*15.88		*17.48		*18.92		*18.73		*17.25		*17.51		*12.72
5		*17.94		*15.92		*16.60		*18.56		*19.24		*18.44		*16.48		*14.72	
Film Centerline → 5	*18.80		*16.70		*16.92		*18.28		*19.60		*19.48		*17.42		*16.88		*13.20
6		*17.76		*15.48		*16.70		*18.88		*19.12		*18.25		*16.68		*13.60	
6	*18.70		*15.52		*16.12		*17.60		*19.70		*18.68		*16.84		*15.67		*12.84
7		*17.60		*14.72		*16.30		*19.22		*19.24		*18.24		*15.33		*14.60	
7	*19.50		*15.44		*15.76		*17.28		*19.64		*18.80		*16.60		*15.24		*11.92
8		*16.36		*14.70		*15.80		*18.48		*18.90		*17.30		*15.00		*12.80	
8	*19.50		*15.90		*15.02		*16.84		*18.68		*18.20		*15.70		*14.60		*11.88
9		*15.80		*13.70		*14.20		*15.60		*16.00		*16.20		*14.32		*13.60	
9	*17.10		*12.44		*11.40		*11.96		*12.60		*13.30		*13.20		*13.40		*11.90
10		*10.10		* 8.65		* 8.20		* 8.70		* 9.08		* 9.80		*11.20		*10.80	

DIRECTION OF FILM TRAVEL
AND
PUMP ROTATIONValues above are inclined manometer
readings in inches.Pressure Plot No. 2A-1
375 RPM

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		* 9.88		* 9.42		* 7.77		* 7.77		* 6.94		* 6.88		* 9.16		* 9.40	
1	*13.23		*12.90		*12.18		*12.28		*11.85		*12.62		*12.60		*14.25		*13.23
2		*14.20		*13.42		*13.63		*15.03		*15.04		*15.04		*14.97		*15.26	
2	*16.10		*14.70		*13.88		*15.46		*17.03		*18.00		*15.27		*16.57		*13.25
3		*15.83		*13.48		*14.90		*16.70		*17.52		*17.18		*16.30		*15.55	
3	*18.22		*14.66		*13.95		*16.06		*17.90		*18.32		*17.20		*15.92		*12.65
4		*16.06		*14.05		*15.45		*17.13		*17.62		*17.14		*15.58		*13.46	
4	*18.22		*14.80		*14.40		*16.49		*18.05		*17.60		*17.26		*14.76		*11.40
5		*16.40		*14.08		*15.43		*17.82		*18.53		*17.71		*15.27		*12.60	
5	*17.67		*15.00		*14.90		*17.70		*18.71		*18.55		*17.42		*15.26		*14.40
6		*16.30		*13.76		*15.97		*18.02		*18.79		*17.86		*15.40		*12.32	
6	*17.41		*14.03		*14.20		*17.15		*19.17		*18.14		*16.28		*14.10		*11.13
7		*16.00		*13.22		*15.53		*18.48		*18.75		*17.70		*14.10		*12.60	
7	*17.88		*13.70		*14.03		*16.55		*19.32		*18.10		*15.92		*13.23		*10.27
8		*14.76		*13.00		*15.04		*18.10		*18.43		*17.50		*13.66		*11.19	
8	*17.86		*14.10		*13.30		*15.70		*17.93		*18.15		*14.54		*13.08		*10.55
9		*14.23		*12.36		*13.75		*15.43		*15.90		*15.26		*12.93		*12.70	
9	*15.32		*11.45		*10.88		*12.12		*12.66		*12.35		*12.47		*11.48		*10.52
10		* 9.15		* 7.60		* 7.47		* 9.23		* 9.23		*10.66		* 9.74		* 9.07	

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches from Pressure Plot
No. 1A-1 multiplied by $\left(\frac{\text{RPM, Plot No. 2A-1}}{\text{RPM, Plot No. 1A-1}}\right)^2$
 $= \left(\frac{357}{296}\right)^2 = 1.454$

Pressure Plot No. 2A-2

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		* 9.96		* 9.82		* 7.95		* 7.58		* 6.36		* 6.36		* 8.83		*10.10	
1	*13.73		*13.54		*12.43		*11.26		*11.26		*12.13		*12.43		*16.46		*14.74
2		*15.83		*14.26		*14.38		*16.91		*17.05		*16.32		*16.18		*17.48	
2	*18.64		*16.12		*15.90		*15.86		*19.36		*20.73		*18.94		*20.50		*14.60
3		*18.28		*15.46		*15.83		*19.57		*20.82		*19.52		*19.74		*17.64	
3	*20.20		*15.80		*15.17		*17.20		*21.80		*21.80		*19.65		*19.36		*13.57
4		*19.88		*15.32		*16.84		*20.73		*21.25		*20.15		*18.86		*14.60	
4	*20.74		*16.11		*15.41		*17.75		*22.23		*21.80		*19.65		*17.64		*12.28
5		*18.35		*15.64		*16.95		*22.05		*22.32		*20.87		*19.23		*13.93	
5	*19.43		*16.84		*16.66		*18.78		*23.27		*22.88		*19.72		*18.21		*12.43
6		*18.00		*15.00		*17.65		*22.40		*22.30		*21.08		*18.85		*13.14	
6	*19.15		*14.96		*15.65		*18.20		*23.10		*21.60		*19.30		*15.40		*12.56
7		*17.92		*14.08		*16.62		*22.80		*22.50		*22.47		*16.18		*14.00	
7	*20.46		*14.76		*15.24		*17.62		*22.83		*22.16		*18.49		*14.60		*11.26
8		*15.96		*14.08		*15.98		*21.65		*20.93		*20.35		*15.03		*12.84	
8	*20.30		*15.38		*14.45		*16.17		*21.80		*21.53		*16.75		*14.36		*11.41
9		*15.12		*12.63		*13.56		*17.33		*17.62		*17.46		*14.72		*13.43	
9	*17.17		*11.83		*11.15		*11.19		*12.63		*13.13		*14.15		*12.26		*11.70
10		* 9.38		* 8.13		* 7.65		* 8.23		* 8.37		* 9.10		*11.26		* 9.97	

DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches from Pressure Plot

No. 3A-1 divided by $\left(\frac{\text{RPM, Plot No. 3A-1}}{\text{RPM, Plot No. 2A-1}}\right)^2$

$$= \left(\frac{420}{357}\right)^2 = 1.384$$

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		*13.80		*13.60		*11.00		*10.50		* 8.80		* 8.80		*12.20		*14.80	
1	*19.00		*18.75		*17.20		*15.60		*15.60		*16.80		*17.20		*22.80		*20.40
2		*21.95		*19.75		*19.90		*23.40		*23.60		*22.60		*22.40		*24.20	
2	*25.80		*22.30		*22.30		*21.95		*26.80		*28.70		*26.20		*28.40		*20.20
3		*25.30		*21.40		*21.90		*27.10		*28.80		*27.00		*27.30		*24.40	
3	*25.60		*21.90		*21.00		*23.80		*30.20		*30.20		*27.20		*26.80		*18.80
4		*23.40		*21.20		*23.60		*28.70		*29.40		*27.90		*26.10		*20.20	
4	*26.20		*22.30		*21.35		*24.54		*30.80		*30.20		*27.20		*24.40		*17.00
5		*24.00		*21.75		*23.45		*30.50		*30.88		*28.90		*26.60		*19.28	
Film Centerline → 5	*24.12		*23.30		*22.30		*23.60		*32.20		*31.68		*27.28		*25.20		*17.20
6		*23.60		*20.75		*24.45		*31.00		*30.90		*29.20		*26.10		*18.20	
6	*24.80		*20.70		*21.80		*25.20		*32.00		*29.88		*26.70		*21.30		*17.40
7		*23.50		*19.50		*23.00		*31.60		*30.90		*29.60		*22.40		*19.38	
7	*26.20		*20.50		*21.10		*22.40		*31.60		*30.70		*25.60		*20.20		*15.60
8		*21.60		*19.50		*22.14		*30.00		*30.40		*28.20		*20.80		*17.80	
8	*26.00		*21.30		*20.02		*22.40		*30.20		*29.80		*23.20		*19.90		*15.80
9		*21.00		*17.50		*18.80		*24.00		*24.40		*24.20		*20.40		*18.60	
9	*22.60		*16.60		*15.60		*15.80		*17.50		*18.20		*19.60		*17.00		*16.20
10		*13.00		*11.30		*10.60		*11.40		*11.60		*12.60		*15.60		*13.80	

DIRECTION OF FILM TRAVEL
AND
PUMP ROTATIONValues above are inclined manometer
readings in inches.Pressure Plot No. 3A-1
420 RPM

TOP CENTER
(Drive End)

		-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
	1		*13.64		*13.04		*10.74		* 9.60		* 9.54		* 9.54		*12.68		*13.00	
1		*17.46		*17.87		*16.86		*17.00		*16.40		*17.46		*17.43		*19.72		*18.32
	2		*19.65		*18.57		*18.88		*20.81		*20.82		*20.82		*20.73		*21.13	
2		*22.25		*20.35		*19.22		*21.40		*23.60		*24.80		*21.54		*22.93		*18.35
	3		*21.90		*18.65		*20.65		*23.10		*24.25		*23.80		*22.54		*21.54	
3		*25.20		*20.30		*19.33		*22.25		*24.80		*25.35		*23.82		*22.08		*17.50
	4		*22.23		*19.45		*21.40		*23.70		*24.40		*23.90		*21.65		*18.65	
4		*25.25		*20.50		*19.92		*22.85		*25.00		*24.40		*23.90		*20.45		*17.50
	5		*22.70		*19.50		*21.37		*24.68		*26.15		*24.50		*21.13		*17.42	
Film Centerline →	5	*24.45		*20.77		*20.60		*24.50		*26.07		*25.55		*24.10		*21.14		*19.92
	6		*22.60		*19.05		*21.90		*24.95		*25.80		*24.70		*21.33		*17.06	
6		*22.05		*19.44		*19.66		*23.74		*26.50		*25.12		*22.55		*19.52		*15.42
	7		*22.20		*18.30		*21.70		*25.40		*25.55		*22.08		*18.31		*14.20	
7		*24.75		*19.00		*19.42		*22.90		*26.76		*25.70		*22.05		*18.32		*14.20
	8		*20.25		*18.00		*20.85		*25.05		*25.50		*24.25		*18.91		*15.49	
8		*24.53		*19.54		*18.42		*21.80		*24.85		*25.12		*20.13		*18.11		*14.60
	9		*19.70		*17.12		*19.04		*21.38		*22.04		*21.13		*17.90		*16.70	
9		*21.22		*15.86		*15.07		*16.78		*17.52		*17.10		*17.26		*15.90		*14.56
	10		*12.66		*10.52		*10.33		*12.78		*12.78		*14.77		*13.48		*12.55	

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches from Pressure Plot
No. 1A-1 multiplied by $\left(\frac{\text{RPM, Plot No. 3A-1}}{\text{RPM, Plot No. 1A-1}}\right)^2$

Pressure Plot No. 3A-2

$= \left(\frac{420}{296}\right)^2 = 2.013$ Approved For Release 2002/09/03 : CIA-RDP78B04747A002800040001-7

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		*14.12		*13.98		*12.18		*11.63		*9.55		*9.41		*12.60		*15.06	
1	*20.50		*19.66		*18.55		*16.90		*15.50		*18.41		*18.13		*21.80		*20.75
2		*22.40		*20.80		*21.20		*21.60		*22.40		*20.95		*20.96		*24.42	
2	*23.95		*22.85		*22.40		*22.53		*23.80		*25.28		*23.27		*25.17		*20.50
3		*24.70		*22.05		*22.70		*24.35		*25.40		*24.10		*24.03		*23.88	
3	*26.15		*22.55		*21.70		*23.87		*26.00		*26.00		*24.10		*25.32		*19.78
4		*24.78		*21.70		*23.80		*24.65		*25.75		*24.25		*23.40		*21.32	
4	*25.45		*22.70		*22.00		*24.20		*26.20		*25.92		*23.88		*24.25		*17.60
5		*24.85		*22.05		*22.98		*25.68		*26.65		*25.53		*22.80		*20.38	
Film Centerline → 5	*26.02		*23.12		*23.42		*25.30		*27.13		*26.95		*24.13		*23.35		*18.27
6		*24.60		*21.42		*23.10		*26.13		*26.48		*25.28		*23.10		*18.83	
6	*25.90		*21.50		*22.30		*24.35		*27.28		*25.88		*23.30		*21.68		*17.78
7		*24.35		*20.38		*22.55		*26.60		*26.63		*25.27		*21.23		*20.22	
7	*27.00		*21.38		*21.80		*23.90		*27.20		*26.00		*23.00		*21.10		*16.50
8		*22.63		*20.35		*21.87		*25.58		*25.18		*23.95		*20.75		*17.72	
8	*27.00		*22.00		*20.80		*23.32		*25.85		*25.20		*21.73		*20.20		*16.46
9		*21.87		*18.95		*19.65		*21.60		*22.15		*22.40		*19.82		*18.84	
9	*23.68		*17.22		*15.80		*16.56		*17.44		*18.42		*18.27		*18.56		*16.48
10		*13.98		*11.90		*11.35		*12.04		*12.57		*13.57		*15.50		*14.95	

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches from Pressure Plot
No. 2A-1 multiplied by $\left(\frac{\text{RPM, Plot No. 3A-1}}{\text{RPM, Plot No. 2A-1}}\right)^2$
= $\left(\frac{420}{357}\right)^2 = 1.384$

Pressure Plot No. 3A-3

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		* 6.88		* 6.73		* 5.62		* 5.38		* 4.63		* 4.60		* 6.21		* 7.09	
1	* 9.13		* 9.32		* 8.72		* 8.20		* 7.87		* 8.72		* 8.74		* 10.31		* 9.84
2		* 10.17		* 9.78		* 9.91		* 10.88		* 11.08		* 10.66		* 10.61		* 11.38	
2	* 11.70		* 10.89		* 10.62		* 10.89		* 12.11		* 12.68		* 11.19		* 12.66		* 9.77
3		* 12.07		* 10.36		* 10.69		* 12.34		* 12.75		* 12.39		* 12.22		* 10.30	
3	* 13.15		* 10.74		* 10.27		* 11.62		* 13.45		* 13.50		* 12.42		* 12.28		* 9.25
4		* 12.04		* 10.32		* 11.49		* 12.75		* 13.16		* 12.55		* 11.73		* 9.95	
4	* 13.36		* 10.89		* 10.49		* 12.05		* 13.56		* 13.32		* 12.45		* 11.42		* 8.62
5		* 12.19		* 10.52		* 11.32		* 13.28		* 13.81		* 13.06		* 11.66		* 9.44	
5	* 12.76		* 11.65		* 11.17		* 12.63		* 14.16		* 13.45		* 12.49		* 11.53		* 9.17
6		* 12.03		* 10.18		* 11.65		* 12.90		* 13.75		* 13.10		* 11.86		* 8.80	
6	* 12.94		* 10.18		* 10.58		* 12.22		* 13.39		* 13.36		* 11.99		* 10.33		* 8.31
7		* 11.93		* 9.63		* 11.17		* 13.22		* 13.49		* 13.14		* 10.44		* 9.43	
7	* 13.19		* 10.07		* 10.31		* 11.79		* 14.15		* 13.00		* 11.69		* 9.87		* 7.67
8		* 11.12		* 9.90		* 10.78		* 13.34		* 13.06		* 12.64		* 10.01		* 8.44	
8	* 13.18		* 10.40		* 9.85		* 11.18		* 13.42		* 13.26		* 10.77		* 9.64		* 9.12
9		* 10.36		* 8.88		* 9.52		* 11.08		* 11.35		* 11.22		* 9.63		* 8.96	
9	* 11.29		* 8.19		* 7.67		* 7.09		* 8.69		* 8.89		* 9.13		* 8.52		* 7.83
10		* 6.56		* 5.59		* 5.35		* 5.99		* 6.11		* 6.78		* 7.38		* 7.14	

→
DIRECTION OF FILM TRAVEL
AND
PUMP ROTATION

Values above are inclined manometer
readings in inches averaged from
Plots No. 1A-1, 1A-2, and 1A-3

Integrated Pressure Plot No. 1
296 RPM (Without Girdle)

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		*10.04		* 9.71		* 8.14		* 7.83		* 6.73		* 6.68		* 9.03		*10.32	
1		*13.92		*13.54		*12.67		*11.91		*11.44		*12.68		*12.71		*15.49	*14.32
2		*15.41		*14.25		*14.36		*15.84		*16.09		*15.50		*15.43		*16.55	
2		*17.03		*15.77		*15.32		*15.86		*17.86		*18.77		*16.49		*18.42	*14.22
3		*17.32		*14.95		*15.71		*17.96		*18.90		*18.03		*17.80		*16.81	
3		*19.10		*15.58		*14.93		*16.83		*19.50		*19.64		*18.08		*17.86	*13.50
4		*17.94		*15.01		*16.39		*18.55		*19.15		*18.27		*17.11		*14.48	
4		*19.35		*15.77		*15.23		*17.24		*19.73		*19.38		*18.05		*16.63	*12.13
5		*17.56		*15.21		*16.33		*19.48		*20.03		*19.01		*16.99		*13.75	
5		*18.63		*16.13		*16.16		*18.25		*20.08		*19.86		*18.38		*16.78	*13.34
6		*17.35		*14.75		*16.77		*19.77		*20.07		*19.06		*16.98		*13.02	
6		*18.19		*14.83		*15.32		*17.65		*20.65		*19.37		*17.47		*15.05	*12.18
7		*17.17		*14.01		*16.15		*19.75		*20.09		*19.47		*15.17		*13.70	
7		*18.93		*14.63		*15.01		*17.15		*20.59		*19.68		*17.00		*14.36	*11.15
8		*15.69		*13.92		*15.61		*19.41		*19.42		*18.38		*14.56		*13.23	
8		*19.22		*15.12		*14.25		*16.23		*19.27		*19.29		*15.66		*14.01	*10.89
9		*15.05		*12.89		*13.84		*16.12		*16.30		*16.30		*13.99		*13.24	
9		*16.53		*11.91		*11.14		*11.75		*12.63		*12.92		*13.27		*12.38	*11.37
10		* 9.54		* 8.12		* 7.77		* 8.72		* 8.89		* 9.85		*10.73		* 9.95	

DIRECTION OF FILM TRAVEL
AND
PUMP ROTATIONValues above are inclined manometer
readings in inches averaged from
Plots No. 2A-1, 2A-2, and 2A-3Integrated Pressure Plot No. 2
375 RPM (Without Girdle)

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		*13.85		*13.40		*11.30		*10.38		* 9.29		* 9.25		*12.39		*14.29	
1	*18.98		*18.76		*17.62		*16.50		*15.83		*17.55		*17.58		*21.44		*19.82
2		*21.46		*19.71		*19.97		*16.50		*15.97		*21.45		*21.36		*23.25	
2	*24.00		*21.95		*21.40		*21.95		*24.40		*25.96		*23.67		*25.50		*19.35
3		*24.30		*20.70		*21.99		*24.85		*26.15		*24.90		*24.62		*23.27	
3	*27.96		*21.64		*20.34		*23.43		*27.00		*27.11		*25.04		*24.73		*18.69
4		*24.25		*20.78		*23.86		*25.68		*26.52		*25.35		*23.62		*20.06	
4	*27.02		*21.95		*21.21		*24.03		*27.30		*26.84		*24.99		*23.03		*17.50
5		*24.59		*21.21		*22.81		*26.95		*27.89		*26.31		*23.51		*19.02	
5	*26.05		*22.62		*22.53		*25.45		*28.46		*28.06		*25.17		*23.23		*18.46
6		*24.25		*20.49		*23.49		*27.36		*27.72		*26.39		*23.51		*18.03	
6	*25.19		*20.58		*21.31		*24.62		*28.59		*26.96		*24.18		*20.83		*16.86
7		*24.29		*19.29		*22.55		*27.86		*27.39		*25.63		*20.64		*17.93	
7	*27.09		*20.32		*20.77		*23.90		*28.52		*27.46		*23.55		*19.87		*15.40
8		*21.77		*19.34		*21.75		*26.88		*27.02		*25.46		*20.15		*17.01	
8	*26.93		*20.94		*19.81		*22.48		*26.96		*26.71		*21.69		*19.40		*15.62
9		*20.86		*17.17		*19.16		*22.34		*22.86		*22.58		*19.32		*18.04	
9	*23.12		*16.47		*15.44		*16.28		*17.48		*17.91		*18.38		*17.15		*15.74
10		*13.07		*11.22		*10.76		*12.07		*12.32		*13.64		*14.86		*13.76	

DIRECTION OF FILM TRAVEL
AND
PUMP ROTATIONValues above are inclined manometer
readings in inches averaged from
Plots No. 3A-1, 3A-2, and 3A-3Integrated Pressure Plot No. 3
420 RPM (Without Girdle)

TOP CENTER
(Drive End)

	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
1		*10.40		*10.60		* 9.20		* 9.40		* 7.80		* 7.06		*10.95		*12.20	
1		*13.90		*14.00		*13.45		*13.40		*12.00		*12.10		*12.70		*15.50	*14.50
2			*15.30		*14.70		*14.80		*14.90		*14.60		*14.83		*16.00		*16.00
2		*16.71		*15.70		*15.00		*16.00		*15.60		*15.66		*16.30		*16.60	*15.20
3			*17.30		*15.00		*15.40		*16.23		*15.93		*16.25		*16.73		*16.43
3		*17.60		*16.50		*15.40		*15.10		*15.60		*15.27		*16.25		*14.70	*12.93
4			*16.40		*14.75		*15.00		*15.80		*15.87		*15.60		*15.75		*15.40
4		*15.40		*15.40		*15.30		*15.65		*16.00		*16.00		*15.90		*15.60	*12.10
5			*15.95		*15.70		*15.80		*15.90		*16.00		*16.00		*15.73		*13.40
5	Film Centerline →	*16.80		*16.60		*15.73		*15.95		*16.10		*16.00		*15.80		*14.66	* 8.60
6			*17.05		*15.65		*15.67		*16.00		*16.03		*16.03		*15.50		*12.30
6		*16.30		*15.75		*15.30		*16.05		*16.10		*16.00		*16.10		*14.83	*10.30
7			*16.80		*14.65		*15.20		*16.10		*16.07		*15.63		*15.00		*13.55
7		*18.81		*16.10		*15.35		*15.60		*15.83		*15.50		*15.70		*13.25	*11.50
8			*15.67		*13.90		*15.50		*17.40		*16.75		*16.20		*15.30		*14.63
8		*18.40		*15.40		*14.37		*16.00		*16.80		*16.60		*16.03		*14.50	*12.80
9			*15.00		*13.63		*14.30		*15.60		*16.00		*15.60		*14.40		*12.83
9		*15.56		*12.70		*12.30		*13.20		*13.67		*14.13		*14.43		*13.67	*13.40
10			*10.80		* 9.77		* 8.83		* 9.33		*10.53		*11.13		*12.27		*11.50

DIRECTION OF FILM TRAVEL
AND
PUMP ROTATIONValues above are inclined manometer
readings in inches.Pressure Plot No. 4
356 RPM (Girdle Installed)

STATINTL

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